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FOREST PEST MANAGEMENT

BIOLOGICAL EVALUATION
R2-91-02

OVERWINTERING EGG POPULATIONS OF PINE SAWFLY, *NEODIPRION AUTUMNALIS*, ON PONDEROSA PINE NEAR FT. MEADE IN SOUTH DAKOTA

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United States Department of Agriculture
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Forest Pest Management
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ABSTRACT

In 1990, a number of outbreaks of the pine sawfly, Neodiprion autumnalis, were reported in western South Dakota and eastern Wyoming. Near Ft. Meade in South Dakota, defoliation in 1990 was heavy at the center of the infestation and decreased to light defoliation at a distance of one mile from the center. Remaining foliage in the lightly defoliated area was three times that of the heavily defoliated area. The majority (62 percent) of remaining foliage at the infestation center was 1990 growth, which is less preferred by this sawfly species than older needles.

Overwintering egg populations were surveyed near Ft. Meade, South Dakota to assess potential for defoliation in 1991. Sample branches (generally 9-14 inches in length) collected at 20 ft. above ground at three sample sites contained averages of between 1 and 2 infested shoots per branch, 10-17 infested needles per branch, and 138-250 eggs per branch. Egg densities were highest at the center of the infestation and lowest one mile out. Average numbers of eggs per needle were between 11 and 15, with means of 2-3 sawfly colonies per branch that contained averages of 60 to 94 eggs per colony. Eggs were laid on all ages of foliage, but were preferentially laid on 1990 foliage at sample sites that were moderately or heavily defoliated in 1990. Only 2-3 needles per sawfly egg are available at the center of the infestation, whereas 8-11 needles are available per sawfly egg at one mile out.

Defoliation in 1991 is expected to be severe at the infestation center with mass starvation of larvae likely. High mortality from starvation and other factors, such as parasites and predators, may contribute to collapse of the population in 1992. Defoliation is expected to be lighter near the perimeter of the infestation and could continue into 1992. Tree mortality is not likely to result from defoliation alone, but drought stress and subsequent infestation by Ips bark beetles may cause small losses. Insecticide application should be considered to protect high value sites; however, no action is needed for most instances because trees can recover following collapse of the sawfly population. Release of parasitic insects to augment the natural enemy population could be effective, but availability may be problematic.

INTRODUCTION

In late July and early August 1990, many private landowners in western South Dakota and eastern Wyoming contacted various county, state, and federal offices concerning heavy defoliation of ponderosa pine (Pinus ponderosa Dougl. ex Laws.) by a pine sawfly, Neodiprion autumnalis (Smith) (Hymenoptera: Diprionidae). In South Dakota, outbreak areas included approximately 1500 acres between Spearfish and Belle Fourche, 300 acres at Ft. Meade, 2000 acres in the northeast corner of Wind Cave National Park and adjacent private property, and windbreaks near Camp Crook (Fig. 1). In Wyoming, approximately 84,000 acres were heavily to severely defoliated in a north-south ridge in eastern Campbell Co. near Gillette, and additional pockets were reported from Linch, Osage, and the Wyoming-Montana border. In many areas, older needles were almost totally consumed and many current-year needles were clipped to within 1-5 inches of the branch. Affected sites tended to be areas of widely-spaced trees with poor growth on dry sites with poor soils. The entire region has been experiencing a drought since 1988.

Neodiprion autumnalis was recently described as a species separate from the N. fulviceps complex (Smith and Wagner 1986). Biologically, N. autumnalis is distinguishable by the fall emergence of adults and the presence of eggs from fall until hatch during spring or early summer. The life history described for a sawfly species at Willits, California is suspected to be that of N. autumnalis (Dahlsten 1961). A univoltine life cycle was described whereby adults emerge from mid-October to early November. The female deposits eggs in rows of slits she cuts in the needle tissue and eggs remain there over winter until mid-March or April. Young larvae feed in groups on needles of the outermost branch tips, initially feeding on the edges of needles. Older larvae completely devour the needles. There are five feeding instars and a sixth non-feeding instar. Larvae drop to the ground in late May or early June to spin cocoons in the duff and litter or as deep as two inches into the soil. Pupation occurs within the cocoon during late September or early October. Larval development in South Dakota and Wyoming in 1990 was observed later than that reported for California, with feeding damage being apparent throughout July and larvae dropping to the ground in late July and early August. Differences in development between these locations might be caused by differences in weather conditions, particularly temperature.

The purposes of this evaluation were to estimate sawfly populations near Ft. Meade using samples of overwintering eggs, determine whether control measures may be needed in 1991, and obtain biological information pertaining to N. autumnalis eggs that could be useful for assessing populations and potential damage levels for future years and infestations.

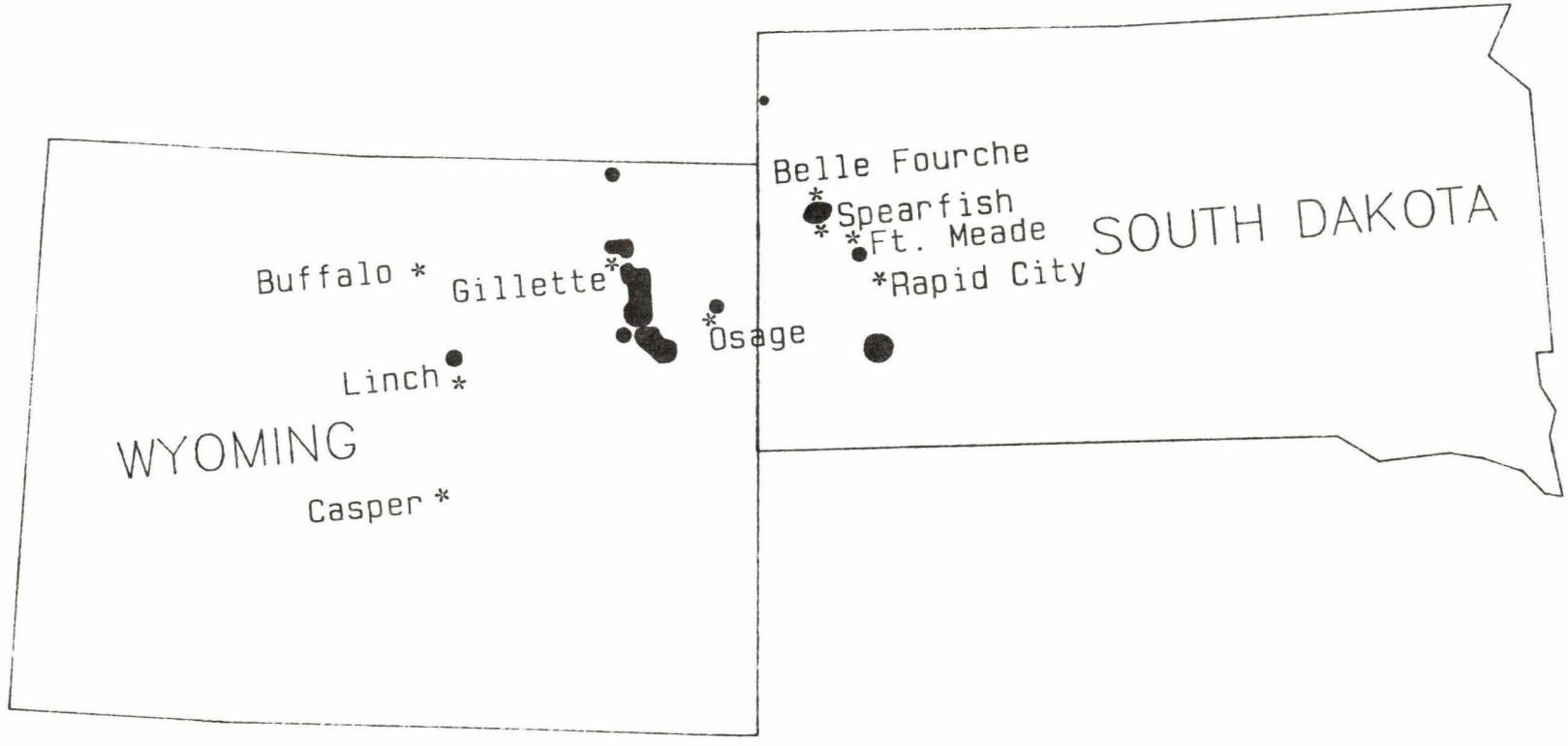

Fig. 1. Distribution of pine sawfly outbreaks in South Dakota and Wyoming.

METHODS

Branch samples were collected from ponderosa pines at three sites near Ft. Meade, SD (on federal land managed by the Bureau of Land Management) on 27 November 1990. Site 1 was located immediately west of the Ft. Meade Cemetery, site 2 was in a draw approximately 1/4 mile southeast of the cemetery, and site 3 was on a ridge about one mile south of the cemetery (Fig. 2). From each sample tree, four branches approximately 2 ft. in length were removed using a pole-pruner from a height of about 20 ft. (approximately mid-crown level). Each of the four branches was collected from a different side of the tree. Twenty trees were sampled at site 1, and 10 trees each were sampled at sites 2 and 3. A few branches also were collected from the lower crowns of trees at sites 1 and 3 using hand pruners.

Sample branches were examined to determine numbers of needles by year of growth (1990, 1989, and 1988 or older--most trees had 4 years of growth), number of needles with sawfly eggs by year of growth, total number of shoots and number of shoots with sawfly eggs, number of sawfly eggs per colony, and number of egg colonies per branch. Needles were counted if at least 2 in. remained; many of the 1990 needles had been partially consumed. A shoot was defined by the presence of a bud and all the needles between it and a branch fork or node. Each brown spot along the edge of infested needles was counted as the presence of a sawfly egg with the exception of the most proximal oviposition slit (thought to sever the resin canal). A sawfly colony included a group of needles in close proximity to each other (separated by not more than a few needles) that contained sawfly eggs. Maximum and minimum values and means were determined for each variable at each site. Values also were calculated for percent of shoots and branches that contained eggs, percent of remaining foliage by year of growth, total needles remaining per sawfly egg, percent of branches without needles by year of growth, percent of branches with sawfly eggs by year of needle growth, number of shoots per sawfly colony, mean number of needles per sawfly colony, mean number of sawfly eggs per colony, mean number of needles per egg for branches containing eggs, mean number of eggs per total needles per branch, and mean number of eggs per infested needle.

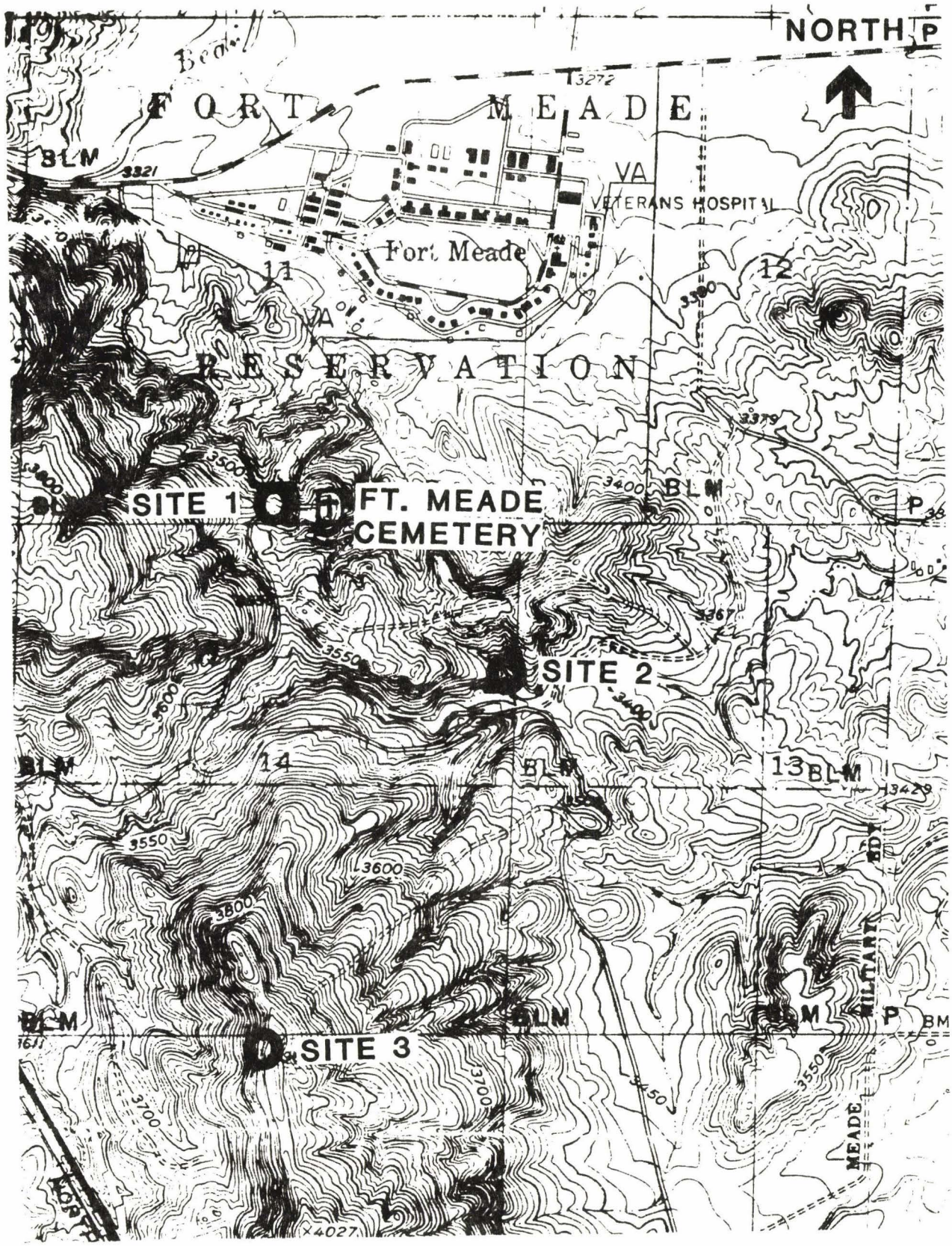

Fig. 2. Location of sample sites near Ft. Meade, South Dakota.

RESULTS

Data on needle abundance and pine sawfly abundance and density are summarized in Tables 1-4.

Needle abundance reflected the general levels of defoliation that occurred during summer 1990 at the three sample sites; site 1 was heavily defoliated, site 2 was moderately defoliated, and site 3 was lightly defoliated. For samples collected at 20 ft., remaining foliage at site 2 was twice that of site 1, and remaining foliage at site 3 was three times that of site 1 (Table 1). The majority of remaining foliage was 1990 growth at site 1, and 41 percent and 51 percent of branches were completely stripped of 1989 and 1988 & older foliage, respectively. Remaining foliage was about equally distributed for 1990, 1989, and 1988 & older needles at site 2, with 10 percent of branches being completely stripped of 1989 or 1988 & older foliage. At site 3, almost twice as many 1988 & older needles remained as 1989 or 1990 needles, and no branches were completely stripped of any year's foliage. Samples collected from lower crowns were shorter and contained less foliage as a result, but similar trends in amount of remaining foliage was apparent relative to corresponding samples collected at 20 ft.

Abundance of pine sawfly eggs was greatest at site 1, intermediate at site 2, and least at site 3, maintaining the general trend in infestation levels from the 1990 population (Table 2). Infested shoots averaged between 1 and 2 per branch and ranged as high as 9 shoots infested per branch at site 1. This represents approximately 10-15 percent of shoots at 20 ft. being infested with sawfly eggs. The percentages of shoots infested in the lower crown samples were higher (about 10-25 percent), but numbers of eggs in relation to available foliage were similar for the two heights at corresponding sample sites. Branches at 20 ft. contained an average of 250, 147, and 138 eggs at sites 1, 2, and 3, respectively. The number of needles per branch infested with eggs averaged about 10 at sites 2 and 3, and about 15-17 at site 1. The number of eggs laid per needle generally averaged between 11 and 15 for the 3 sites and 2 sample heights (Table 3). Most eggs were deposited along one edge of a needle, but a few rare instances of eggs being laid on both sides of a needle were noted.

Sawfly eggs were laid on all ages of foliage, but relative abundance varied by site (Tables 2 & 4). At site 1, where the majority (62 percent) of foliage was 1990 growth, the vast majority of sawfly eggs (82 percent) were laid on 1990 foliage. At site 2, where foliage was approximately evenly distributed by age class, eggs were most abundant on 1990 foliage (51 percent) and least abundant on 1988 & older foliage (14 percent). At site 3, where the oldest needles were most abundant (47 percent, generally representing 1988 and 1987 growth), sawfly eggs were preferentially deposited on 1989 foliage (55 percent) at 20 ft. and on 1990 foliage (51 percent) in the lower crown. The percentage of branches that contained eggs on various ages of foliage showed similar trends.

Table 1. Values of needle abundance for ponderosa pine branch samples collected from lower crown and at 20 ft. in November 1990 near Ft. Meade, South Dakota.

BRANCH VARIABLE	LOW SITE 1 (n = 10)	20 FT. SITE 1 (n = 80)	20 FT. SITE 2 (n = 40)	20 FT. SITE 3 (n = 40)	LOW SITE 3 (n = 8)
Branch length (in.)					
Minimum	11	11	9	14	14
Maximum	23	54	34	37	21
Mean ± SD	18.0 ± 4.1	26.5 ± 6.6	24.1 ± 4.7	22.8 ± 4.9	16.5 ± 2.3
No. 1990 needles					
Minimum	77	21	51	69	125
Maximum	491	800	1006	1680	241
Mean ± SD	252.6 ± 135.8	342.2 ± 210.0	419.7 ± 244.3	434.1 ± 287.3	179.6 ± 42.3
No. 1989 needles					
Minimum	0	0	0	2	85
Maximum	424	991	899	813	385
Mean ± SD	130.0 ± 151.4	115.8 ± 183.2	319.3 ± 240.0	357.5 ± 204.8	221.9 ± 96.3
No. 1988 & older needles					
Minimum	0	0	0	3	122
Maximum	372	1340	1390	1949	856
Mean ± SD	109.9 ± 173.7	91.3 ± 220.1	435.1 ± 341.5	705.0 ± 435.9	459.9 ± 287.7
No. needles/branch					
Minimum	106	60	241	487	413
Maximum	919	2474	2712	3543	1364
Mean ± SD	492.5 ± 248.6	549.2 ± 397.6	1174.2 ± 559.4	1496.7 ± 764.1	861.4 ± 351.1
No. shoots/branch					
Minimum	4	2	5	4	5
Maximum	15	90	33	52	46
Mean ± SD	7.4 ± 3.4	16.5 ± 14.8	14.5 ± 7.2	19.8 ± 11.6	14.9 ± 13.1
% branches w/o needles					
1990	0	0	0	0	0
1989	30.0	41.2	10.0	0	0
1988 & older	50.0	51.2	10.0	0	0
All	0	0	0	0	0

Table 2. Values of pine sawfly egg abundance for ponderosa pine branch samples collected from the lower crown and at 20 ft. in November 1990 near Ft. Meade, South Dakota.

BRANCH VARIABLE	LOW SITE 1 (n = 10)	20 FT. SITE 1 (n = 80)	20 FT. SITE 2 (n = 40)	20 FT. SITE 3 (n = 40)	LOW SITE 3 (n = 8)
No. shoots with eggs					
Minimum	0	0	0	0	1
Maximum	4	9	5	6	2
Mean ± SD	1.9 ± 1.1	2.0 ± 1.7	1.4 ± 1.4	1.6 ± 1.6	1.4 ± 0.5
% shoots with eggs					
All samples	25.7	12.2	9.5	8.1	9.2
Mean/branch	26.2 ± 13.9	15.9 ± 13.6	11.8 ± 15.0	9.2 ± 12.6	14.7 ± 10.7
No. needles with eggs					
Minimum	0	0	0	0	4
Maximum	40	68	59	62	16
Mean ± SD	15.4 ± 11.5	17.4 ± 17.4	10.0 ± 12.5	10.0 ± 13.2	10.4 ± 4.6
No. eggs/1990 needles					
Minimum	0	0	0	0	0
Maximum	458	1068	435	156	181
Mean ± SD	139.1 ± 155.5	205.6 ± 264.5	75.4 ± 117.9	25.6 ± 45.0	57.1 ± 69.1
No. eggs/1989 needles					
Minimum	0	0	0	0	0
Maximum	153	368	304	785	125
Mean ± SD	28.3 ± 59.9	33.0 ± 70.3	51.0 ± 77.1	76.5 ± 153.9	15.6 ± 44.2
No. eggs/1988 & older needles					
Minimum	0	0	0	0	0
Maximum	109	264	231	187	105
Mean ± SD	18.5 ± 35.6	11.0 ± 42.1	20.6 ± 50.9	34.9 ± 54.7	38.9 ± 39.7
No. eggs/all needles					
Minimum	0	0	0	0	25
Maximum	458	1084	779	913	181
Mean ± SD	185.9 ± 136.0	249.6 ± 273.6	147.0 ± 173.5	137.9 ± 186.4	111.6 ± 57.2
No. sawfly colonies					
Minimum	0	0	0	0	1
Maximum	6	10	11	12	3
Mean ± SD	2.5 ± 1.8	2.7 ± 2.4	2.2 ± 2.5	2.3 ± 2.7	1.6 ± 0.7

Table 3. Values of pine sawfly eggs per individual infested needle for ponderosa pine branch samples collected from the lower crown and at 20 ft. in November 1990 near Ft. Meade, South Dakota.

BRANCH VARIABLE	LOW SITE 1 (n = 10)	20 FT. SITE 1 (n = 80)	20 FT. SITE 2 (n = 40)	20 FT. SITE 3 (n = 40)	LOW SITE 3 (n = 8)
No. eggs/individual infested needle for all needles:					
Minimum	1	1	1	1	1
Maximum	29	41	45	30	22
Mean ± SD	12.0 ± 7.6	14.8 ± 7.2	14.5 ± 6.7	13.5 ± 6.1	10.6 ± 5.4
for 1990 needles:					
Minimum	1	1	1	1	1
Maximum	28	41	45	27	22
Mean ± SD	12.9 ± 7.6	15.0 ± 7.2	16.2 ± 7.4	15.5 ± 6.1	13.8 ± 5.2
for 1989 needles:					
Minimum	1	1	2	1	1
Maximum	29	37	36	27	16
Mean ± SD	14.9 ± 8.8	13.7 ± 6.6	13.3 ± 5.5	14.2 ± 6.1	9.6 ± 4.8
for 1988 & older needles:					
Minimum	2	1	2	1	1
Maximum	13	29	30	30	19
Mean ± SD	6.8 ± 3.4	13.1 ± 7.2	12.9 ± 5.9	11.5 ± 5.5	8.4 ± 4.6

Table 4. Values of pine sawfly population density for ponderosa pine branch samples collected from lower crowns and at 20 ft. in November 1990 near Ft. Meade, South Dakota.

BRANCH VARIABLE	LOW SITE 1 (n = 10)	20 FT. SITE 1 (n = 80)	20 FT. SITE 2 (n = 40)	20 FT. SITE 3 (n = 40)	LOW SITE 3 (n = 8)
% branches with eggs					
1990	80.0	63.8	45.0	37.5	62.5
1989	20.0	25.0	40.0	42.5	12.5
1988 & older	30.0	11.2	22.5	42.5	62.5
All	90.0	82.5	62.5	65.0	100.0
No. needles/colony					
Minimum	1	1	1	1	2
Maximum	15	28	17	16	13
Mean ± SD	6.2 ± 3.8	6.3 ± 4.8	4.7 ± 3.2	4.4 ± 3.2	6.4 ± 3.2
No. eggs/colony					
Minimum	3	2	5	2	23
Maximum	236	468	249	264	125
Mean ± SD	72.4 ± 58.6	93.7 ± 76.1	67.6 ± 48.9	59.6 ± 50.1	68.7 ± 37.7
Total No. shoots/ No. colonies	3.0	6.2	6.6	8.6	9.2
Total No. needles/ No. eggs	2.6	2.2	8.0	10.8	7.7
Needles/egg for branches with eggs					
Minimum	0.6	0.4	2.1	1.8	2.3
Maximum	13.3	78.5	31.8	425.2	23.4
Mean ± SD	3.8 ± 3.9	7.1 ± 15.4	8.2 ± 7.4	27.7 ± 81.6	10.7 ± 7.4
Eggs/needle for all branches					
Minimum	0	0	0	0	0.1
Maximum	1.6	2.5	0.5	0.6	0.4
Mean ± SD	0.5 ± 0.5	0.6 ± 0.7	0.1 ± 0.2	0.1 ± 0.1	0.2 ± 0.1
% of total eggs laid on:					
1990 needles	74.8	82.4	51.3	18.6	51.2
1989 needles	15.2	13.2	34.7	55.5	14.0
1988 & older	10.0	4.4	14.0	25.3	34.8
% of total needles by age					
1990 needles	51.3	62.2	35.7	29.0	20.8
1989 needles	26.4	21.1	27.2	23.9	25.8
1988 & older	22.3	16.6	37.0	47.1	53.4

The number of sawfly colonies per branch averaged about 2-3, but ranged as high as 12. For the different sample locations, the number of needles per egg colony averaged between 4 and 6, and the number of eggs laid per colony averaged between 60 and 94. A number of unusually large colonies were noted particularly at site 1 that might actually have been 2 colonies that were laid so close together that they could not be separated visually. One colony was present for every 6-9 shoots at 20 ft.; density was higher for the lower crown at site 1 with a sawfly colony present for every 3 shoots.

Egg densities in relation to available foliage were highest at site 1 and lowest at site 3 (Table 4). At site 1, there were only 2-3 needles available per sawfly egg. At site 2, there were 8 needles available for every egg. At site 3, there were 8-11 needles available for every sawfly egg. Since these values were calculated from overall needle and egg counts at each site, they do not reflect variations in distribution from branch to branch or tree to tree. Thus, means were calculated for branches that contained eggs, and they ranged from a low of 4 needles per egg per infested branch for site 1 lower crown samples to a high of 28 needles per egg per infested branch at site 3 20 ft. samples.

DISCUSSION

Some egg deposition characteristics at the Ft. Meade location were similar to those reported for the Willits and Mt. Shasta (Site 1) populations in California, suggesting that these populations may indeed represent the same species; however, there were a few differences in egg distribution. Stark and Dahlsten (1965) reported a preference for oviposition on current year's foliage with 58-67 percent being deposited there and 30-40 percent being deposited on 1-year-old foliage at Mt. Shasta, California. A similar trend was evident for sites 1 and 2 at Ft. Meade where defoliation in 1990 had been moderate to heavy; however, the pattern was quite different at site 3 where defoliation had been light.

The mean number of eggs laid per needle was slightly lower at Ft. Meade (11-15) than for ponderosa pines at Willits (17.1) and Mt. Shasta (19.5) in California (Dahlsten 1966). The mean number of eggs per needle appeared to decrease with increasing needle age (current year: 20.0; 1-year: 16.7; 2-year: 13.5) at the Mt. Shasta site, but was not statistically significant (Stark & Dahlsten 1965). Numbers of eggs per needle were relatively constant for different ages of foliage at Ft. Meade, except for older foliage (1989 & older) in lower crown samples where sample sizes were small.

The number of eggs laid per colony were similar for the Ft. Meade and California populations and probably represent the full compliment of eggs of a given female, provided disturbance does not occur during egg-laying. Dahlsten (1961) estimated that a female could lay between 60 and 80 eggs, and average number of eggs per tip were 61.4 and 80.9 at Willits and Mt. Shasta, respectively (Dahlsten 1961, 1966). Dahlsten assumed one sawfly colony per tip, but sometimes more than

one colony per tip was present at Ft. Meade and counted separately. The mean number of eggs per colony at Ft. Meade sites 2 & 3 fell between 60 and 70 and probably best represents the number of eggs a female will lay. The higher mean number of eggs per colony at site 1 was likely the result of a number of instances of coalescence of colonies caused by extremely high population densities.

Because N. autumnalis prefers to feed on older foliage, the 1990 foliage that was generally avoided by larvae feeding during 1990 will become a primary food source for larvae feeding during 1991. However, where 1989 and older foliage was heavily defoliated in 1990, total available foliage suitable for feeding by pine sawfly larvae will be reduced in 1991. Based upon the numbers and densities of sawfly eggs present in the overwintering population, massive starvation is likely to occur, especially at site 1, during 1991 (following extensive defoliation). No figures have been documented as to how many needles an average larva consumes during the course of its development, but it is certain to be more than the 2 needles available per egg at site 1, and even the 8-11 needles per egg available at site 3 is not an excessive amount for a sawfly larva, known to be a ravenous feeder. A slightly higher number of needles may actually be available per feeding larva because of some mortality of eggs and first-instar larvae. Larvae that run out of food on a given branch or tree exhibit wandering behavior in search of food, and can readily be seen crawling up and down tree trunks and across the ground (Dahlsten 1961). This behavior can be expected in the 1991 population at Ft. Meade, particularly for later instars.

In the absence of artificial control measures, defoliation can be expected to be heavy to severe at the center of the infestation (site 1), moderate to heavy at 1/4 mile from the population center (site 2), and moderate at one mile from the population center (site 3). Although no areas beyond one mile were sampled, the infestation is likely to include a somewhat larger area in 1991 relative to 1990. Although defoliation levels can be expected to be heavy, tree mortality directly resulting from this pine sawfly species (or closely related species) has not been reported even after complete defoliation of older needles (Dahlsten 1966). Apparently the presence of enough uneaten current year needles is sufficient to sustain the trees under normal circumstances. The current drought affecting defoliated trees at Ft. Meade will contribute additional stress; a small percentage of trees might die under this condition, but extensive tree mortality is not anticipated.

Pine sawfly populations typically collapse following one or two years of epidemic levels as a result of mortality from a combination of parasites, predators, disease, starvation, and other natural causes, such as adverse weather conditions. Because of the high reproductive potential of females, mortality of 95 percent of the sawfly population (from egg to adult) is necessary just to maintain population levels (Dahlsten 1967). Small increases in mortality above 95 percent contribute to rapid decline of an infestation. The high larval population densities predicted for the center (site 1) of the Ft. Meade infestation in 1991 will likely contribute to disease spread and

starvation, which result in high mortality of larvae and pupae and reduced fecundity of surviving females. Thus, the center of the infestation can be expected to collapse following the 1991 feeding period. The population might continue at high levels into 1992 along the perimeter of the infestation (site 3), where populations will not be quite as high in 1991.

Sawfly mortality varies through the stages of development and at different times during the course of an infestation. Such factors are difficult to assess for a given population without extensive, on-going study. However, mortality trends can be expected to generally follow that reported by Dahlsten (1967) from life table studies of the Mt. Shasta, California population. Total mortality during the 1-year study was 99.2 percent and contributed to a downward trend of 31 percent in the egg population the following year.

Egg parasitism is expected to be low; it was 5 percent in the Mt. Shasta study. No evidence of egg parasitism was detectable in the overwintering egg samples at Ft. Meade; however, parasitism generally is not noticeable until eggs begin to swell in spring. Egg mortality resulting from cold temperatures and competition from other needle-feeding insects was high at Mt. Shasta, but is not expected to be a significant factor at Ft. Meade due to a differing climate, lower elevation, and absence of competing insects.

Larval mortality can be significant just following hatch (25 percent at Mt. Shasta) caused by inability to emerge from the egg pocket due to excessive drying, failure to establish at a feeding site, entrapment in water droplets, being dislodged from the tree, and other adverse weather factors. Drying of egg pockets could be a significant factor at Ft. Meade because of drought conditions. Mortality of feeding larvae (2nd-5th instars) typically is low, with some predation occurring. Parasitism that occurs during larval stages does not become apparent until the cocoon stage (i.e., feeding continues after the larva becomes parasitized). Disease was not detected in the Mt. Shasta larval population but is common in related sawfly species; it is not known whether diseases are present at Ft. Meade. Anticipated larval mortality due to starvation is likely to be greatest toward the end of the feeding period. Additional mortality likely will result after larvae drop from trees to the ground (43 percent of prespinning larvae or 16 percent of original population at Mt. Shasta).

The cocoon stage is especially vulnerable to attack by a number of parasites and predators, particularly insects and small mammals. Additional mortality can result from disease (Beauveria bassiana (Bals.) identified at Mt. Shasta). Total loss of cocoons was 93 percent at Mt. Shasta, but may not be this high in South Dakota. Adults emerged from about 40 percent of cocoons collected during late summer 1990 in Butte Co., South Dakota (personal communication, Rich Dorset, South Dakota Division of Forestry). However, no estimate of predation was determined. Predators consumed 33 percent of cocoons at Mt. Shasta. Parasite adults emerged from 6 percent of the Butte Co. cocoons and another 8 percent represented unhatched cocoons that likely contained spring-emerging parasites. This is much lower than

the rate of parasitism of cocoons (43 percent) at Mt. Shasta. Mortality due to disease or unidentified causes were similar for Butte Co. and Mt. Shasta populations; 5 percent of unhatched cocoons were covered with fungus and 15 percent died of undetermined causes in the Butte Co. sample. The relatively low parasitism rate in South Dakota in 1990 likely contributed significantly to the development of high egg densities in the overwintering population and will contribute to perpetuation of the epidemic beyond one year. The parasitism rate in 1991 is likely to be a key factor in determining whether pine sawfly populations will continue to cause significant defoliation beyond 1991. Augmentation of the parasite population might be feasible if active pine sawfly outbreaks can be located in the Lake States or elsewhere so that parasites can be collected for release in South Dakota.

ALTERNATIVES

Alternative 1: Insecticide Application - Foliage can be sprayed aerially or using ground equipment with an appropriately registered chemical insecticide, such as carbaryl (Sevin) or malathion. Application should be timed to coincide with the presence of less than full-grown larvae (2nd to 4th instar), which are likely to occur in June to early July in South Dakota depending upon weather conditions.

Alternative 2: Biological Control - Parasitic insects can be released to augment the natural enemy complex. Availability of parasitic insects for release can be problematic.

Alternative 3: Do Nothing - Accept defoliation as a natural phenomenon. Pine sawfly populations typically decline rapidly within a couple years following the initiation of an outbreak and most trees recover.

RECOMMENDATION

For most non-timber producing sites, the cost of applying insecticides can not be justified in relation to the resource values (wildlife, recreation, aesthetics, etc.). The do nothing alternative may be best for most of these sites. Parasitic insects could be released if an adequate supply can be produced.

Insecticide application should be considered for high value sites, such as recreation and historical sites, where protection of aesthetic character and shading is important. The Ft. Meade Cemetery can be considered a high value site, and the importance of protecting trees from defoliation in the immediate vicinity of the cemetery should be evaluated. Small treatment blocks within larger areas of infestation are likely to be reinfested in subsequent years until the local population collapses.

Insecticide application also may be an appropriate alternative where trees weakened by pine sawfly defoliation have a high probability of subsequent infestation by other insects that can directly cause tree mortality, such as pine engraver beetles (Ips). Currently, numerous pockets of tree mortality caused by Ips occur throughout the area infested by the pine sawfly; Ips populations are high throughout the Black Hills area in response to a drought that has continued since 1988. However, additional tree mortality is not expected to significantly impact resource values (although numerous additional infestation pockets can be expected for at least a couple years depending upon precipitation levels). A few trees at the north end of the Ft. Meade Cemetery have been killed by Ips. Placement of several pheromone traps to collect emerging Ips adults in the vicinity of infested trees may be the best alternative to reduce spread of the beetles in and around the cemetery.

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